Stress Inoculation through Cognitive and Biofeedback Training

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ABSTRACT

This paper describes a new technology that blends cognitive training to anticipate the effects of stress with advanced biofeedback to mitigate stress effects and aftereffects, using a simulation-based framework. In an increasing number of military personnel, the adverse effects of service and particularly of stressful combat exposure are significant, long lasting and possibly fatal. Most stress research is focused on treatment, but because stress effects are liable to appear years after exposure, it is imperative that methodologies be developed to mitigate the adverse effects of military-related stress and prevent its post-exposure effects. It has long been accepted that warfighters adapt to combat stress after the first few experiences and that training can help duplicate this process, with recent studies showing that experienced military personnel are able to control and even utilize stress productively. A key part of what experienced personnel learn is self-awareness of their stress state and self-regulation of stress effects. These skills can be greatly enhanced by combining cognitive learning methodologies grounded in learning theory and biofeedback techniques based on Heart Rate Variability (HRV) with innovative simulation game-based training tools. The training system described here will be implemented on a mobile device such as an iPod/Touch, providing adaptive, tailored training that can be widely distributed to the Warfighter for initial stress resilience training, on-the-spot refreshment and practice.

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INTRODUCTION

Stress and PTSD

In an increasing number of military personnel, the adverse effects of service and particularly of stressful combat exposure are significant, long lasting and possibly fatal. The incidence of post-traumatic stress disorder (PTSD) rose 50% in 2007 over the previous year, and the known total of over 40,000 cases is probably severely underreported (Tyson, 2008). The Army suicide rate has also reached a 28-year high and is undoubtedly related to the PTSD figures (US Army, 2010). Much research and clinical attention is now directed to PTSD, which is associated with emotional distress, family problems and cognitive disabilities as well as work performance (Vasterling, 2007). Most PTSD research is focused on treatment, but because stress effects are liable to appear years after exposure, it is imperative that current research and development efforts also be focused on establishing new technologies to mitigate the immediately adverse effects of military-related stress and prevent its post-exposure effects.

Stress and Survival

The ability to deal with stress before and while it occurs is a determinant not only of performance and survival in combat, but also of post-occurrence reactions (Army Science Board, 1998; Zakay, 2010). Enhancing such ability is of paramount importance to the military, as well as to paramilitary organizations such as police, firefighters and security forces. It has long been accepted that warfighters somehow adapt to combat stress after the first few experiences and that training can help accelerate the process. Studies have shown that survival rates among fighter pilots dramatically increase after the first few missions (Weiss, 1966). Similar survival rate variations have been observed in the domain of infantry combat, although there is a lack of corresponding statistical data. A Defense Science Board (DSB) study found that highly realistic ground combat training at the National Training Center has produced dramatic performance improvements in subsequent training evaluations (Defense Science Board, 2001).

Military Stress Control Programs

Because stress has a significant influence on performance in the field as well as on psychological health after exposure, the US military has mounted several programs intended to mitigate stress effects both on active duty personnel and their families. For example, the Navy's Combat and Operational Stress Control (COSC) Program has taken a hard stance on combat and operational stress control. Its message being: addressing stress problems early is a sign of strength, and not dealing effectively with stress is a sign of weakness. Taking charge of your life and showing you can deal with stress head-on is much better that pretending it doesn't exist (Koffman, 2007). The Navy's Stress Continuum Model helps personnel recognize stress effects in themselves and others – and provides a non-threatening way to talk about this very personal topic. The US Army has also started a program to introduce stress mitigation techniques to soldiers and their families during training (Carey, 2009).

Stress Resilience Training Current Needs

The current programs, while very well intentioned, still leave some substantial training needs. Personnel contact is concentrated on classroom exposure and mainly disseminated using literature and limited internet contact. Available guidance material is useful, but tends to be rather general in terms of individual and familial stress factors. In addition, guidance materials are primarily "broadcast media" rather than interactive and personalized media. Training in biofeedback methods for controlling stress is moving in the right direction and increasing in scope -- but has yet to reach its full potential. And most important, personnel are not yet able to take focused and motivating interactive training materials with them into operational environments. Accordingly, there is a need for interactive, specific, and personalized training to deal with pre-exposure, exposure and post exposure situations that can be delivered in the field as well as the classroom.

SCIENTIFIC AND TECHNICAL APPROACH

Main Premises

The current approach to meeting the training needs described above rests on the following main premises:

- Science-based pre-exposure stress resilience training that incorporates both cognitive factors and biofeedback techniques will minimize adverse stress effects and enhance positive stress effects; i.e., the productive use of stress energy;
- Minimizing the adverse effects of stress at the time of exposure will help prevent the occurrence of post traumatic stress disorder (PTSD);
- State-of-the-art mobile training delivery will greatly improve training effectiveness by permitting on-the-spot refreshment and practice;
- Game-based and fun eLearning will motivate younger personnel to use these mobile devices and gain the training benefits;

Utilizing Stress Productively

The key hypothesis underlying the current work is that the difference between novice and expert lies in how each manages stress. This is a marked departure from other approaches which assume that experts simply do not experience stress. That experienced personnel are able to mitigate and even productively utilize stress has been shown in several important studies. The seminal research in this domain is that of pilot survivability in air-to-air combat in WWII and Korea conducted by H.K. Weiss (1966), in which he showed that the chance of combat death or injury decreases significantly with repeated exposure.

The difference in performance of experienced vs. inexperienced troops was shown dramatically by the Army Research Institute (ARI) simulation study of performance under stress conducted at the Presidio of Monterey (Berkun, 1964). In this study the ARI investigators exposed military personnel to a set of realistically simulated dangerous situations that would never pass today's Institutional Review Boards for the protection of subjects.

In one test the investigators compared experienced and inexperienced troops in a supposedly live fire artillery exercise where the impact explosions moved steadily toward a forward observer subject, who was then asked to fix a field radio so the controllers could better understand his frantic calls to stop the barrage.

The outcome was counterintuitive. For the raw recruits, the results were as expected: Higher reported stress and poorer performance in the ‘dangerous’ situation as compared to a control situation. But for the experienced troops the results were opposite. These troops performed better in the 'stressful' situation than in the 'non-stressful' control situation, and actually reported more stress in the control situation than in the artillery situation. The results suggested that the stress the experienced troops experienced under dangerous friendly fire was being put to positive use to ameliorate the danger. Such mitigation and productive use of stress has been reported in other contexts as well, as described below.

For example, a pioneering set of studies of parachutists by Fenz et al (1967 & 1972) addressed directly the strategies experts use to control stress effects. Figure 1 shows the self rating of stress by inexperienced and experienced jumpers in one study.

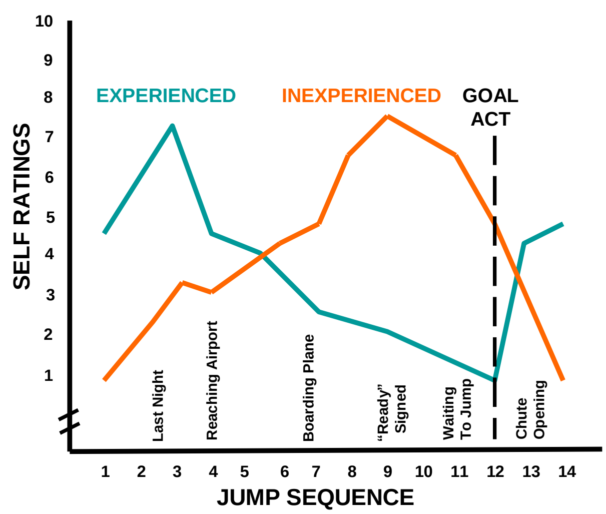

Figure 1. After Fenz & Epstein (1967)

While both groups showed equal levels of stress, the reported stress for experienced parachutists peaked 24 hours before the jump, while that for the inexperienced parachutists peaked at the jump itself! Continuous recordings of skin conductance, heart rate, and respiration rate showed similar trends. The authors stated, “*The most adaptive autonomic response pattern, the one related to the best performance, is shown to be that of an increase in arousal early during the jump sequence, followed by a sharp decrease in arousal which extends to the time when the subject exits from the aircraft. (This) supports earlier findings that fear of a stressful event does not simply dissipate, but rather is inhibited or controlled. Individual differences, in the extent to which a person has learned to cope with his* *fear, do arise. The study shows that while repeated exposure to a stressor is an important variable, there are also other variables which are responsible for differences between subjects in their ability to deal effectively with stress."* Similar results have been reported by Weltman et al (1966 & 1971) in their studies of stress effects in novice SCUBA divers.

More recently, CAPT Lori Laraway, Coordinator of the Navy's Operational Stress Control Program, said: "*Stress is not necessarily a bad thing; in fact, it's necessary for health. Stress often leads to quick clear thinking and heightened energy. It's a normal and expected response to demanding circumstances, and it can push us to higher levels of performance when used to our advantage. Just as world-class athletes gain the winning edge by using every means at their disposal our world-class sailors need to employ all means available to stay fit and ready and to seek assistance for stress reactions before they become stress problems"* (Viahos, 2010). Consideration of visualization techniques used by athletes confirms that stress can be productive if self-regulated and controlled (Pfeffermann, 2010; Robbins, 2010).

Nature vs. Nurture

The conclusions from these studies are three-fold. First, when properly managed, stress can be performance enhancing. Second, the ability to manage stress distinguishes experienced individuals from non-experienced individuals. Finally, enabling individuals with the ability to manage stress is a powerful approach to realizing stress resilience. Consequently, a key underlying issue is the trainability of stress resilience. A Defense Science Board studying strategies for achieving Training Superiority (DSB, 2001) pointed out that Weiss (1966) himself believed that aces were born and not made – the best survived and the worst got shot down. However, the DSB Task Force members believed otherwise. Their assessment was that the subsequent Navy "Top Gun" school and later the Army National Training Center showed the ability to reduce the probability of casualty through the application of appropriate training, and that consequently it is feasible to train to the "ace" level. This conclusion is supported by recent surveys and studies (e.g. Fletcher & Tobias, 2006; Thayer, 2009).

HRV Coherence Training for Stress Resilience

Satisfactory performance in stressful combat and operational situations depends largely on the ability to control the neuropsychological responses associated with counter-productive emotional states such as anxiety, fear, and despondency. A key part of what experienced personnel learn is self-awareness of their stress state and self-regulation of stress effects, as described further below.

McCraty and colleagues have shown in a series of studies that neural signals from the heart affect the brain centers involved in neurophysiologic and emotional self-regulation, and thus are central to various types of cognitive and psychomotor performance (McCraty 2001; McCraty et al, 2006). The conclusion, which contradicts previous ideas, is that the heart sends more information to the brain than the brain sends to the heart, so that regulation of heart rhythm is a critical component of stress control and emotional well being. These studies also established a link between emotions and cognitive function and a unique neurophysiologic measure: a strong and regular pattern of beat-to-beat heart rate variability (HRV). This strong and regular pattern is termed "*coherence*."

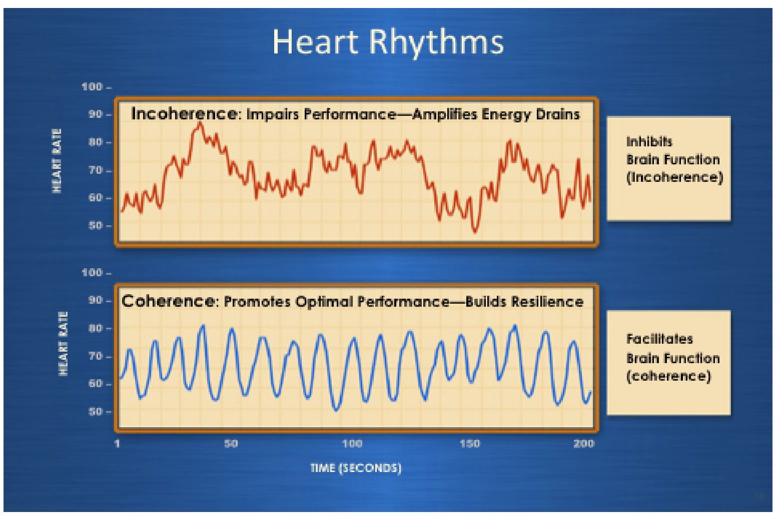

Figure 2. Examples of Coherent and Incoherent Heart Rhythms

Figure 2 contains two typical graphs showing the same person's beat-to-beat heart rate over several minutes' time. The top graph shows the edgy, jerky pattern associated with *incoherence*. Incoherence means that the sympathetic and parasympathetic nervous systems are out of synch; it represents the neurophysiology of poor mental and physical performance. The bottom graph shows the more even pattern associated with *coherence*, when the sympathetic and parasympathetic nervous systems are in synch. It represents the neurophysiology of positive emotions, when everything seems easy and cognitive performance is high. Athletes call this *THE ZONE*.

Game-Based eLearning

It is clear that many of the effects of combat and operational exposure can be achieved through simulation (Cohn, Nicholson & Schmorrow, 2009). For example, the Marines Corps Infantry Immersive Trainer (IIT) facility at Camp Pendleton reportedly elicits essentially the same reactions as real combat (Jones, 2010). Simulation works because the virtual environment is enough like the real experience to cause the same reactions. This depends to some extent on having had the experience previously. But even if the simulated environment doesn't elicit the exact same effects as actual life-threatening situations, it can still trigger reactions very similar to those expected when the real world exposure occurs.

Full-scale immersive simulations are very expensive and require a significant support infrastructure. At the same time many of the same interactive experiences and training benefits can be achieved with games on laptop and handheld platforms (Green & Bavelier, 2003; Greitzer, Kuchar & Huston, 2007). For example, a "Virtual Iraq" that is built around USC's Institute for Creative Technology PC-based Full Spectrum Command game is being used to treat PTSD by therapist-guided *prolonged habitation*, in which stress cues are gradually separated from the narrative activities, so that the patient can later relive the traumatic narrative without experiencing the stress effects.

Moreover, games have a distinct motivational factor for today's youthful military personnel, who are used to game-play in their off-duty lives. Finally, games controlled by the user's biology, e.g., HRV-controlled games, provide a unique and highly immersive gaming experience. These findings have been adopted in the SRTS, as described below, so that trainees learn to maintain coherence while progressing from easy to highly challenging levels of HRV-controlled games, culminating in a complex first-person shooter game that has most of the characteristics of a full-scale war fighting simulation.

System Concept

The Stress Resilience Training System (SRTS) combines validated algorithms for measuring HRV and the level of coherence (McGraty, 2001; McCraty et al, 2006), with game-based training approaches to teach individuals to correctly assess their immediate emotional state, to achieve coherence and to shift from negative to positive emotions. Users learn to build and store resilience and to improve both immediate performance and long-term emotional well being.

Figure 3 shows the SRTS concept, which offers a new, multidimensional approach to the design and delivery of stress resilience training. The system incorporates learning components derived from two distinct but

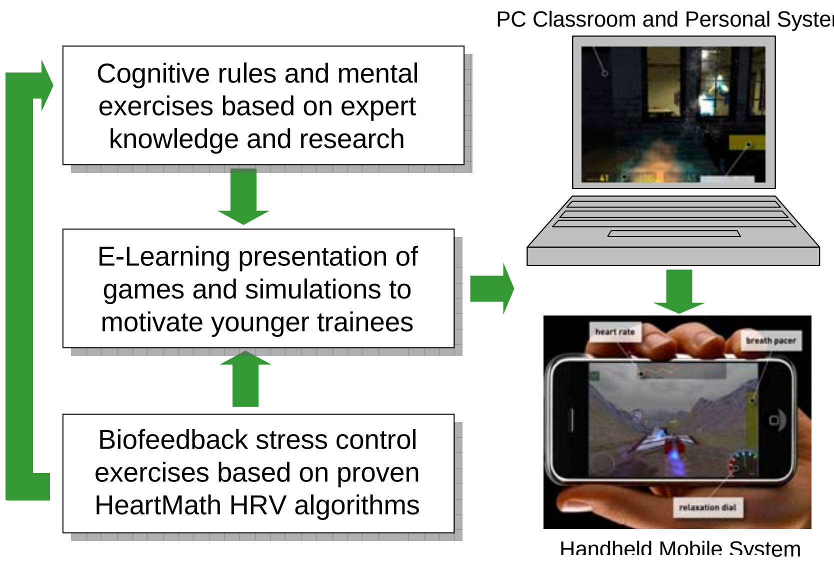

Figure 3. Stress Resilience Training System Concept

complementary sources: cognitive rules based on research and expert knowledge, that we have termed "Know How;" and HRV-based coherence building techniques based on HRV-assessing algorithms.

Two types of delivery platform are currently in development: The PC platform will support classroom instruction and personal training in unit facilities or at home; the handheld mobile platform will accompany the user to the field, for training before and after stressful exposure.

- Plan for system growth and adaptability from the start, including tailoring for different user groups.

System Organization

Figure 4 is a screenshot of the SRTS main menu taken from the current PC-based proof-of-concept software. The proof-of-concept is a fully operational end-to-end system, but its training modules are not yet fully populated with the planned content.

Figure 4. SRTS Main Menu Screenshot

Design Goals

The system design goals have been adapted to the current conditions of military stress control principles, emphasizing the goals and approach of the Navy's OSC and COSC programs. Design specifications were developed in consultation with the leaders of these programs during the design and proof-of-concept phases

The main design goals are to:

- Present scientifically proven stress resilience and related emotional fitness content and techniques in a context that is *understandable, motivating, useful and effective.*
- Configure the system for its actual expected users as well as expected conditions of use. The latter means: predominantly younger personnel; leaders as well as troops; multiple ranks and experiences; multi-ethnic population; and for women as well as men.

The system contains a number of administrative functions, such as registration of users and help, and also provides for a future online community of users. There is an introductory video that is intended for single use, but can be repeated if desired. A professional voice-over artist narrates the introduction and the training modules.

The training content itself is divided into three main categories, each accessed by a pull-down menu showing a number of related but stand-alone modules. The categories are described to the user as follows:

- *The first part of the training – Know How – provides a wealth of information about stress and stress resilience: what this is, why it matters to you, and how to use resilience training in all phases of your mission.*
- *The second part – Techniques -- introduces "Coherence Advantage" a proven military biofeedback training program that teaches you*

how to bring yourself into the best mental and physiological state for stress resilience.

- *The third part – Games -- uses a set of biofeedback-driven games to help you achieve mastery of your Coherence Advantage technique.*

The individual training modules of each main area are intended for youth viewing, i.e., they are short (about 2 minutes) and designed for "non-linear" access – similar to iPhone or iPod apps rather than linear textbooks or conventional computer-based training courses. An Adaptive Coach guides the user through the content, and suggests new modules based on his or her progress. A variety of feedback formats shows the user's progress to date within a given training module and across the entire training set.

Cognitive Know How

The main goal of the Know How section is to have the user understand the meaning and importance of stress resilience, and to provide him or her with useful rules that will help inoculate against negative effects of stress and promote positive use of stress in conjunction with the coherence-building techniques. The current Know How modules are: Resilience, Preparation, Performance and Recovery. Concerning resilience, the user is told:

Stress is our mental, physiological and emotional response to situations that challenge our capabilities. Stress is sometimes dramatic, as when dealing with the chance of death or injury in combat. But stress is also just part of every day life, such as job troubles or relationship worries. Whatever the source, stress should be dealt with to prevent it from becoming a serious problem.

Having stress resilience, and knowing how to store and use your energy productively, will give you the staying power to handle even long lasting challenges. An important part of resilience is being able to bounce back ***after*** *a challenging experience. But research shows that resilience is much bigger than just bouncing back. That is, resilience* ***during*** *stressful situations is even more important in order to prevent immediate and future negative effects.*

Coherence Training

The SRTS coherence training techniques are adapted from HRV feedback programs that have been successfully applied by HeartMath in both classroom and individual settings. The techniques involve the use of a simple and reliable ear pulse sensor and signal conditioner that is connected to the SRTS platform, and center on two primary concepts: coherence breathing and emotion shift and reset.

- Coherence Breathing. Simple screen graphics show the user's average heart rate, a breath pacer and immediate coherence level. The user is asked to imagine that his breath is flowing in and out of his heart area to calm him down and reduce the intensity of any stressful reactions. The user is then instructed to take casual, slow, deep breaths: inhale for 5 seconds — exhale for 5 seconds.
- Emotion Shift and Reset. This all-important step trains the student to be aware when something is causing an energy drain and lowering resilience. Common examples are situations that cause fear, impatience, frustration, anger. Another one is overload -- too much to do and not enough time to do it. Such negative emotions drain energy reserves, By contrast, *positive emotions* are "high octane fuel" for energy reserves. Shift and reset trains the user to recognize the negative emotion, to breath coherently, and to mentally choose an appropriate positive emotion to *reset* his or her system and counter the energy drain. For example, fear can often be countered by evoking feelings of courage or duty to others. While the shift may be temporary, continued practice results in longer lasting effects, and to the ability to achieve and maintain coherence in many situations.

HRV-Controlled Games

The use of HRV-controlled games for practicing and mastering the coherence breathing technique is a truly distinctive feature of the SRTS. The games are presented in ascending levels of difficulty, with maintenance of coherence the main factor in each of them. The Adaptive Coach advises the user when the next level is achievable, or if he or she should drop down a level to hone their coherence skills. At the lower difficulty levels, maintaining a coherent state allows the user to view an interesting and calming pattern, to control the growth of a flower, or even to build an entire suburban home. At the higher difficulty levels, the user must contend with an action-packed environment and at the highest level with armed opponents and realistic dangers.

Figure 5 shows the HRV-controlled Dual Drive game, which is of medium to high difficulty. In this game the user is able to choose the type of car and the course on which he or she will race against other computer-driven cars. At medium difficulty, the user's car is automatically steered through the course, at high difficulty, the user must steer manually. The user has to maintain coherence to move the car forward; the higher the coherence level, the greater the speed.

Figure 5. HRV-Controlled Dual Drive Game, Desert Racer on the Lava Course

The screen shot shows the unique feedback features of the SRTS presentation. At the bottom left is a breath pacer display, which is either set by the user to a comfortable level or adaptively adjusted by the HRV monitoring system. Here it is set to 7.5 seconds/breath. The user is instructed to breath in synch with the progressing sine wave. Above this is a display of the user's immediate heart rate and actual HRV rhythm. Here the heart rate is 49 and the HRV is ragged. The numerical coherence level being achieved is shown by the bar at the lower right, the colors of which match the Navy COSC program's Stress Continuum. In this case, the user is at a 65% coherence level. This low level is draining his energy, which is shown on the fuel gage above the coherence bar. If the coherence stays low, all the energy will be drained, the car will halt, and the Coach will advise a new action. Additional displays in the screen provide the user with information about the game: the course map appears at the left, and a position score at the upper right. At present the user is leading the race despite his problematic coherence level.

Mobile Platform

With respect to choice of mobile platform, potential systems include the iPod and the Android handheld devices. The iPod has an advantage in current market share, but the Android seems to be gaining, and has the important advantage of a more open system. The Defense Advanced Research Projects Agency (DARPA) recently specified Android in a SBIR announcement asking for innovative military apps for handheld platforms, and the US Army appears to be moving toward an Android specification.

However, a survey of potential end-users of the SRTS indicated a definite desire for a tablet-sized platform such as the iPad (Figure 6 below). The rationale is that field users will not be placing the handheld in their pockets, so very small size is no benefit, and the larger tablet screen gives almost the size, resolution and immersion of a laptop without its bulk and weight.

The current plan is to choose a tablet for implementing the SRTS Phase II mobile prototype, but to also build in the capability to support the software on the iPod as well as on other still-to-be-announced devices.

Figure 6. SRTS Mock-Up on an iPad Tablet

POSITIVE INITIAL EVALUATIONS

The PC-based SRTS system has been demonstrated to a number of potential user groups, including:

- US Navy Center for Combat and Operational Stress Control (NCCOSC), San Diego;
- US Navy Operational Stress Control (OSC) Program, Washington DC;
- US Marine Corps Warfighter Lab, Point Loma;
- US Navy Special Warfare Group (SEALs), San Diego.

The initial evaluations have been uniformly positive and enthusiastic. Comments by the NCCOSC leadership and staff included … *it's great; very engaging. Could give it to our guys. We would like to work with it, go forward with pilots for evaluation." "..will be happy to facilitate getting it out there -- thinking of five groups we could immediately set up pilots with -- for example, SEALs and Marines." "Catches my attention all the time. Will work with adolescents*." These informal assessments and validations will be followed up by more formal tests and trials of a full system, but the early results are certainly encouraging, and provide a strong incentive for rapid implementation and full fielding.

CONCLUSIONS

Project Planning

The Phase I SRTS proof-of-concept has shown the feasibility of building a usable, useful *and fun* stress resilience training system with integrated cognitive and biofeedback content in a game-based eLearning framework. In Phase II the major development steps will be: (1) to implement the complete system on a mobile handheld device, most likely a tablet, as well as on the current PC; and (2) to arrange with a suitable activity for field evaluations and first transition activities. While mobile implementation presents some technical challenges, we believe they are surmountable using available technology.

Evaluation, Transition and Commercialization

The value proposition to potential evaluation and transition partners includes the following benefits:

- SRTS becomes an important tool in for improving performance during stressful exposure and preventing PTSD after exposure
- SRTS fits immediately with the objectives of the Navy's Combat and Operational Stress Control program by providing a new capability for broad delivery to units and on-site sustainment training
- SRTS also fits immediately with the objectives of other stress control and resiliency training programs, including law enforcement, security, institutional and industrial applications.

At the same time, the costs to the cooperating activity are minimal, involving primarily:

- Some development support in terms of domain expertise, evaluations and progress reviews
- Assuming demonstration of validity and utility, inclusion in partner's program, NETT training on SRTS, and assistance with initial dissemination to selected units

Based on the initial responses, we are confident that we will secure an evaluation and transition partner within the Navy OSC and COSD programs.

The planned evaluation process begins with usability studies involving focus groups to provide feedback on the system content and design, lab test and evaluation to ensure that the target groups are able to operate and learn from the system, and field test to ensure that the lab results hold up in practice. Our Phase II effectiveness studies will likewise begin with structured tests in a simulated environment and move to full field evaluation in the selected activities.

The transition and commercialization plan is based on initial transition to selected Navy units, followed by more widespread dissemination to Navy and Marine Corps activities. Our goal is integration into the Armed Forces as a whole, with simultaneous marketing and sales to non-military civil activities, clinical institutions, corporations, etc. Our project partners Ease Interactive and Institute of HeartMath are highly experienced in commercial sales of biofeedback based products, and accordingly our sales expectations are high.

Relationship with Future R&D

There is naturally a widespread interest in the military and elsewhere in strategies for preventing the adverse effects of stress during and after performance in a variety of risky, dangerous environments. The current effort extends previous research and practical experience to provide a new, coherent, empirically supported and feasible set of methods and tools for training such strategies. Specifically this effort is: (1) extending the knowledge framework of stress inoculation and mitigation; and (2) providing integrated training based on critical thinking about actual stress resilience techniques, and (3) implementing a mobile system that contains these features.

Previous attempts to conceptualize the competencies and traits underlying resilience to stress and combat survival have generally failed to identify and analyze actual behavioral complexes that occur when survival strategies succeed and when they fail. For example, emphasis on static traits or skills may divert attention from the flexibility and improvisation that are required to invent effective strategies on the fly in dynamic situations. With respect to training, findings are often too general and ill-defined to provide the required concrete guidance for interpersonal skill development.

One of the most innovative contributions of the present approach is its practical realization of a theoretically sound, empirically grounded, and pragmatically useful level of analysis. This should open up new and fruitful avenues of research. The present effort will help consolidate and extend earlier research work in a natural way, by demonstrating its practical application to achievable and effective training for improved stress inoculation and survival skills. This integration will facilitate the important task of reducing immediate and post-exposure stress injuries.

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